Increasing the Reliability and Accuracy of Automated, On-Line, Carbon-in-Ash Measurements

Ed Burgher, Tom Hope
eburgher@rpco.com
thope@rpco2.com

Rupprecht & Patashnick Co., Inc.
www.rpco.com

Topics

- Review of R&P On-line CIA Monitor History
- Our Approach to Improving Accuracy and Reliability of an On-line CIA Monitor
- Recent Experience / Field Trials

TEOM Series 4100
Automated, On-line CIA Monitor

- Originally Designed and Offered as an On-line LOI monitor (~1988).
- Added CO_2 Monitor to Eliminate Measurement Interference from Oxidation of Non-Carbon Species (sulfur, iron) (~1992)
- Participate in EPRI / Southern Co. Sponsored Evaluation of Automated CIA Monitors (1999)
- Begin Redesign of R&P Monitor based on Findings of EPRI/SC Study, Review of Customer Repair/Support Logs, Marketing Study

EPRI / Southern Co. CIA Monitor Evaluation Study Series 4100 Performance and Findings

- **Positives**
  - Easiest Installation of All Automated CIA Monitors

    +Doesn't Require Outage.
  - Highest Precision & Accuracy, Not Sensitive to Combustion Changes, Coal Type.
  - Startup Performance - Best of All Monitors.
  - Routine Maintenance - Higher than desired, but easy and not time consuming.
  - Constant Sample and Analysis Time - Independent of Load/Cycles.

EPRI / Southern Co. CIA Monitor Evaluation Study Series 4100 Performance and Findings

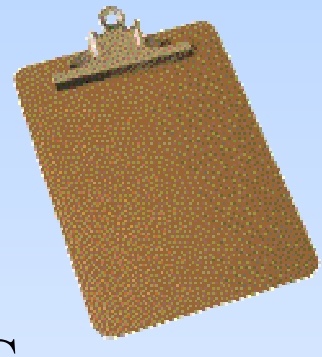
- **Negatives**
  - Low Availability, Low Reliability, High Non-Routine Repairs/Service (related to filter, furnace heating element and sample transfer (silicone) tubing components)
  - In addition to above performance related issues, monitor also needed:
    - Replacement of filter cartridge and repair to burnoff heater assembly due to operator error in misaligning burnoff heater during maintenance.
    - Replaced sample probe nozzle to increase sample time.

TEOM Series 4200 Monitor
What Is It?

- A rugged, automatic monitor for determining the carbon content of fly ash (in percent) at coal-burning facilities.
- The monitor uses first principles to determine the mass and carbon content of collected fly ash.
- This second-generation device incorporates proven sample handling and analysis techniques, and is designed for reliability and minimal maintenance requirements.

Carbon-in-Ash Test

Series 4200 Combustion Efficiency Monitor



1) Collects a fly ash sample isokinetically.
2) Transports the fly ash to the Sample Station.
3) Weighs the fly ash sample collected on the filter.
4) Heats the sample in a high-temp furnace to 800ºC.
5) Measures the amount of CO_2 generated during the sample oxidation process.
6) Calculates the percentage of carbon in the fly ash.
7) Reports information to plant personnel and systems.
8) Recycles to start another test.

Operational Considerations

- Sample collection and analysis *both* take place at the collection filter—no sample transport.
- Open loop measurement of CO_2 from oxidation provides for reliable carbon determination.
- Analysis process produces very little waste.
- Carbon measurements performed without being influenced by sulfur, iron or boiler additives in the fly ash sample.

Calculations

- Total Mass: $$\Delta M = K_0 * \frac{1}{\left(f_1^2 - f_0^2\right)}$$

- CO_2 Mass: $$CO_2(kmol) = \frac{vol_{CO_2}(l)}{22.4\left(\frac{l}{gmol}\right)}$$

- C Mass: $$C(gmol) = CO_2(gmol)$$

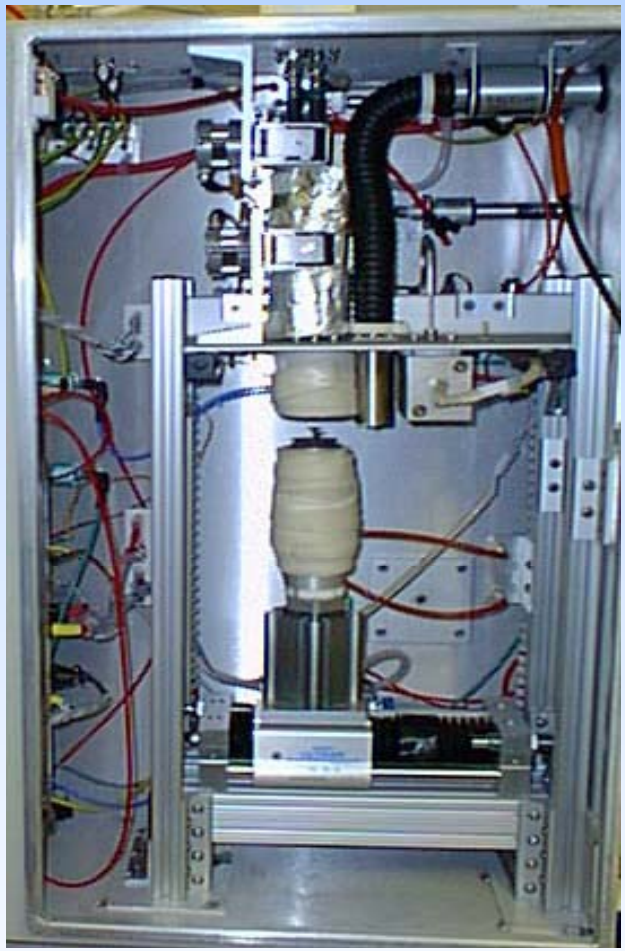
$$C(g) = C(gmol) * 12.011\left(\frac{g}{gmol}\right)$$

- %CIA: $$\%CIA = \frac{C(g)}{TM(g)} * 100\,\%$$

Hardware Overview

Series 4200 Combustion Efficiency Monitor

Series 4200 Enclosure with Umbilical and Probe at Top (Prototype Unit)



Sample Processing Section of Instrument

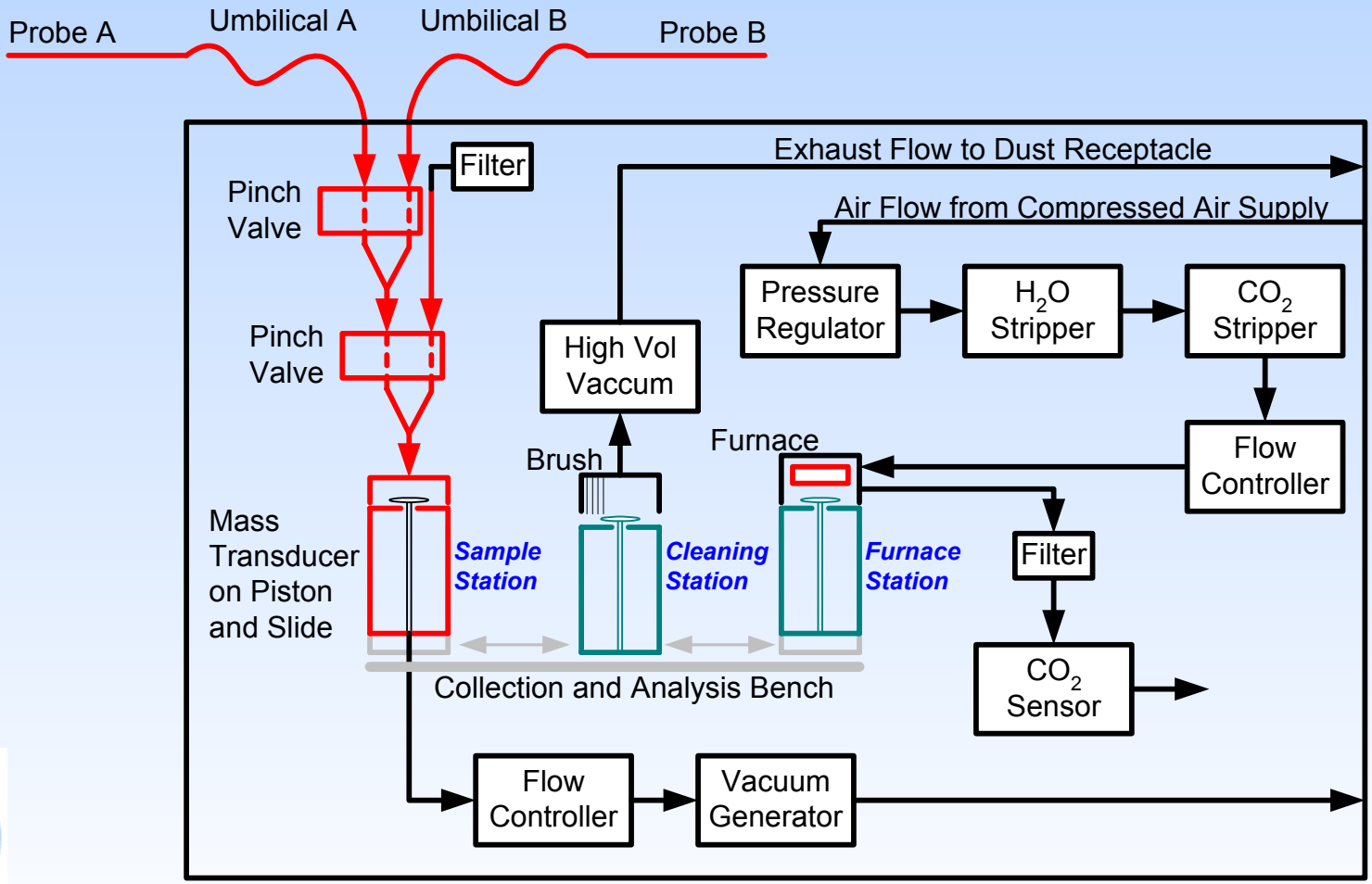
Major System Components

Series 4200 Combustion Efficiency Monitor

- Heated probe and heated umbilical line deliver the sample to the monitor. Probe bundle includes probe for collecting manual sample. Optional second probe permits two point, time-shared sampling.
- Industrial-grade microbalance for fly ash mass measurement.
- Sample analysis system, including furnace and NDIR CO_2 meter.
- Collection and analysis bench positions the mass transducer at different locations.

System Schematic

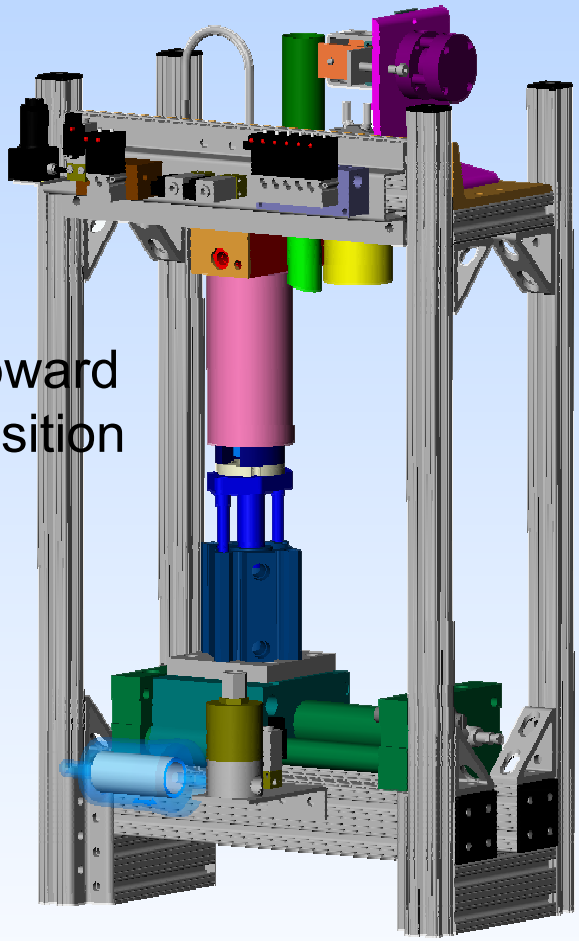
TEOM Series 4200 Combustion Efficiency Monitor



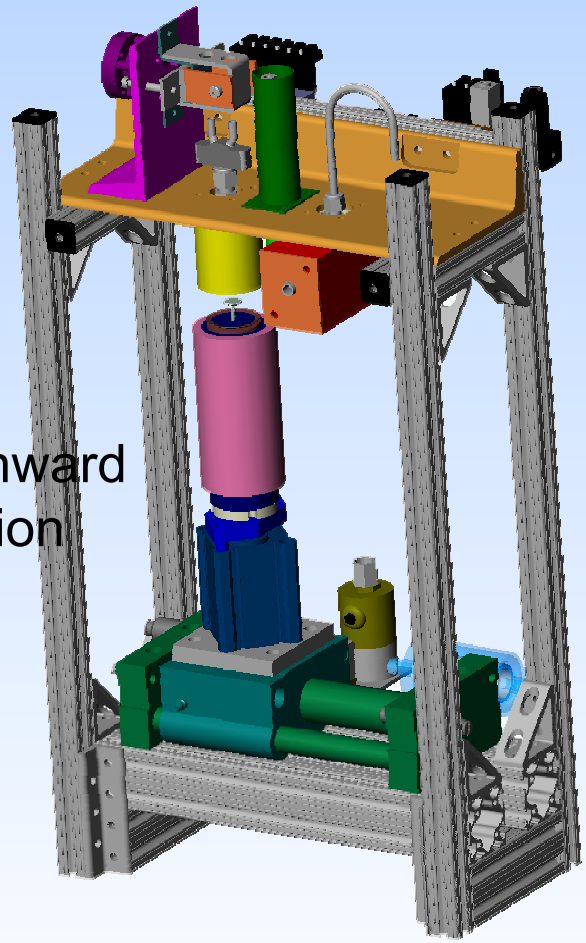
Mass Transducer Positions

Sample Station

Upward Position

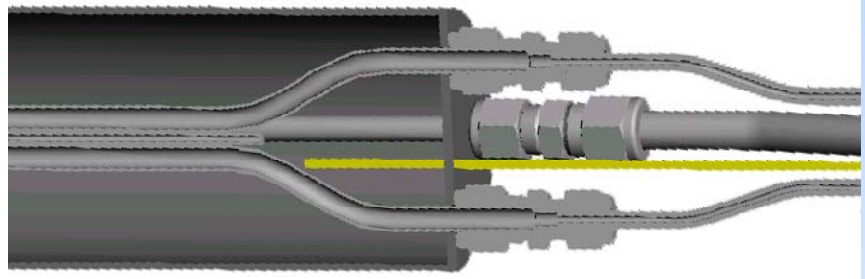


Downward Position



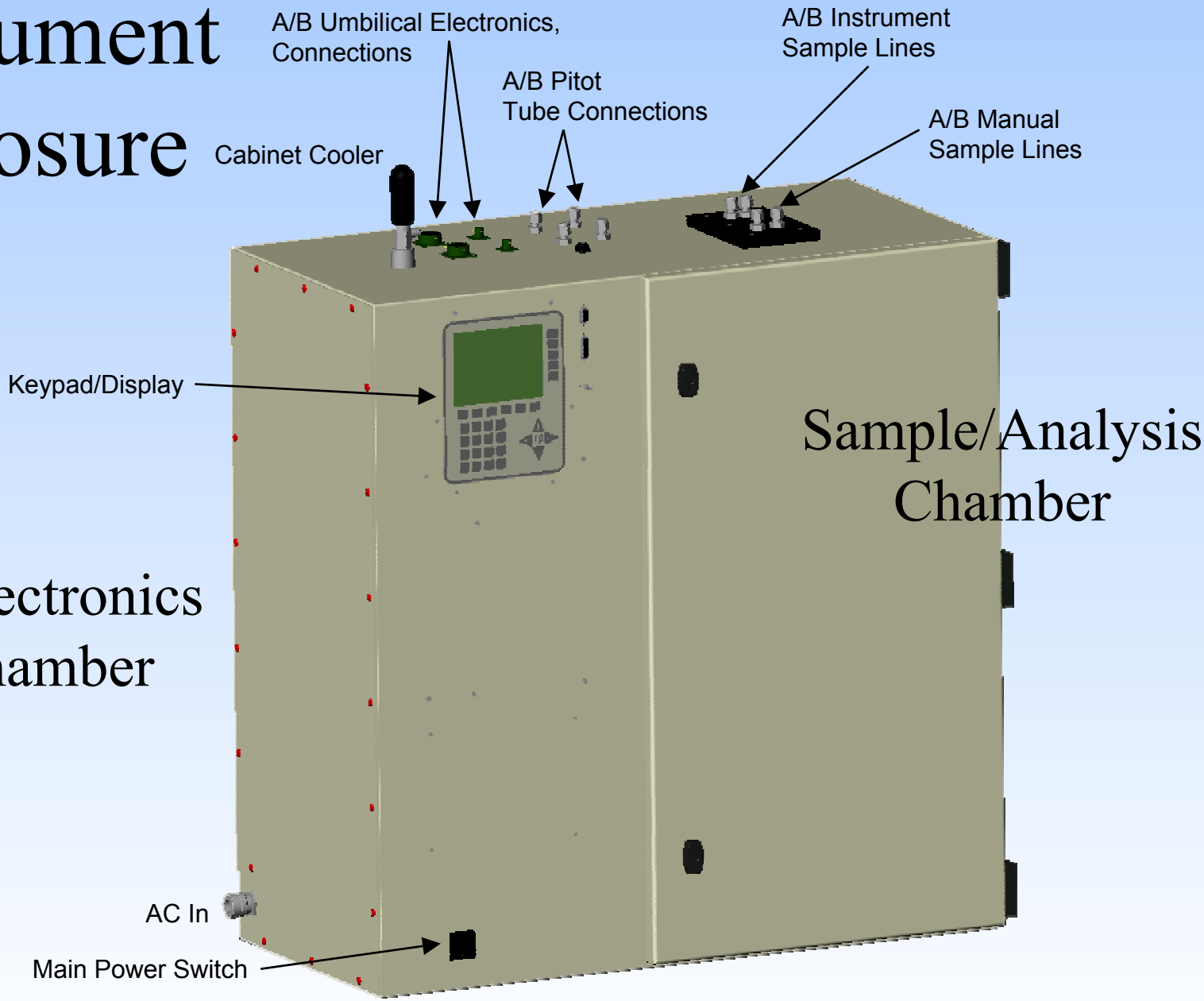
Heated Probe/Umbilical Line

Series 4200 Combustion Efficiency Monitor

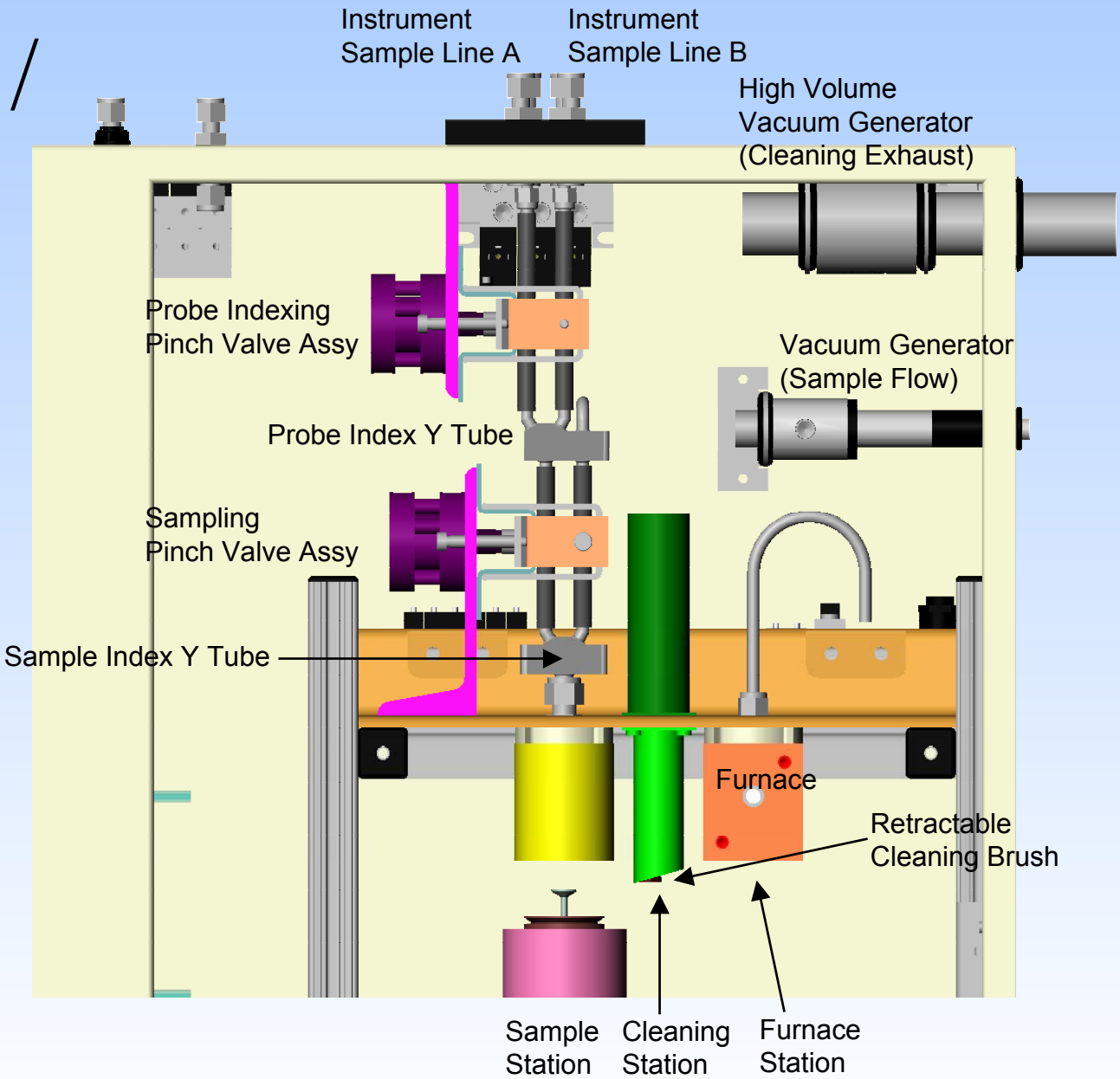


Transition Between Heated Probe and Inlet Section

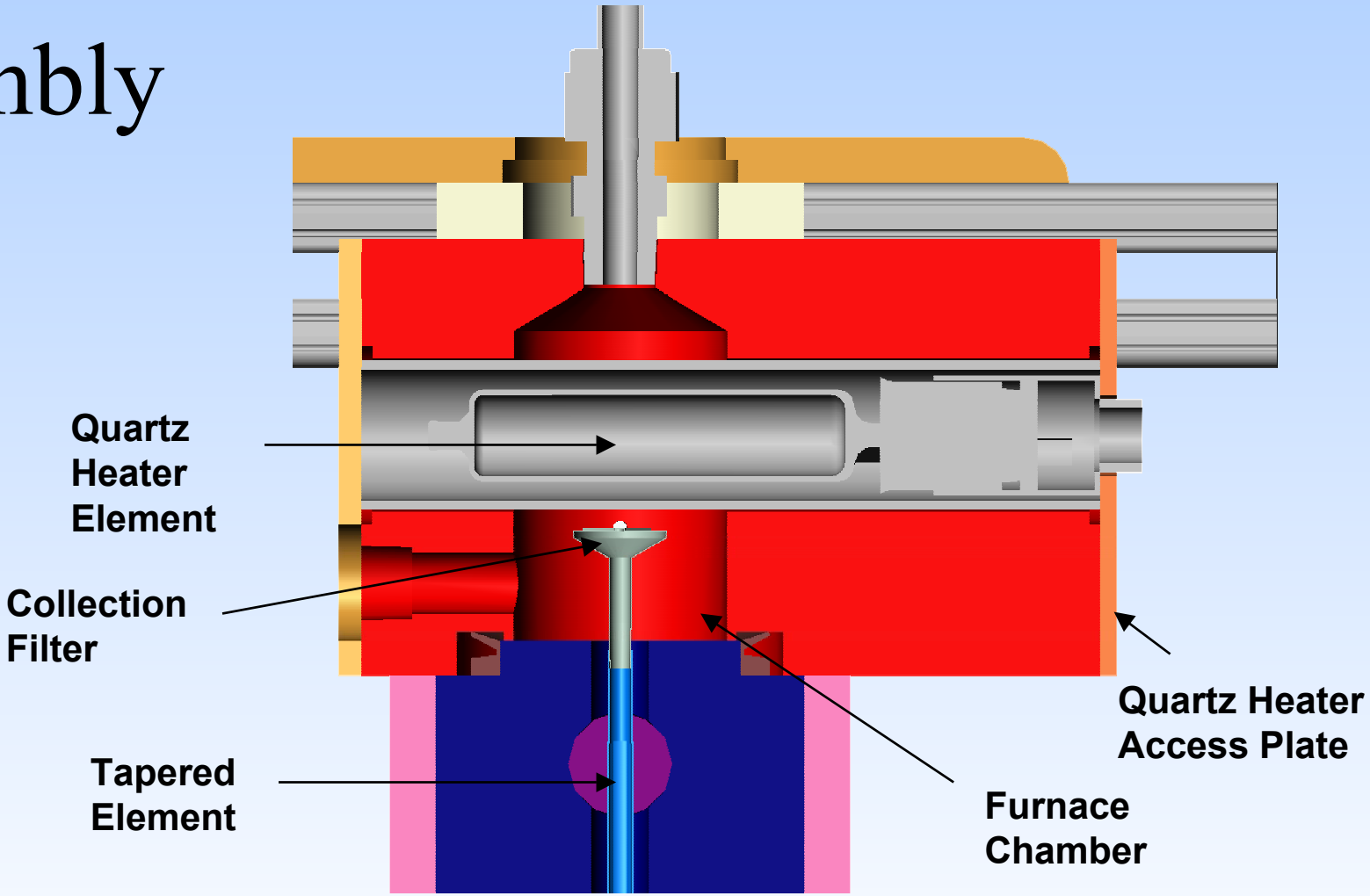
Instrument Enclosure



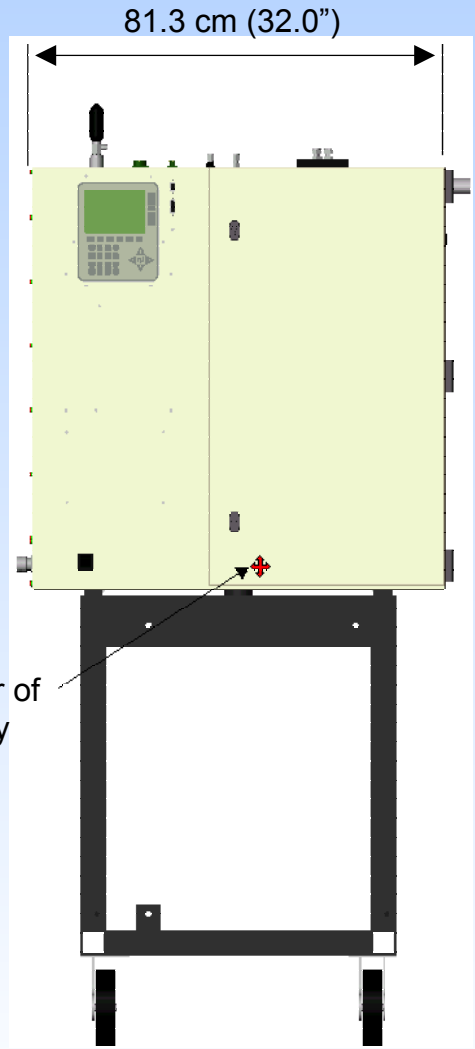
Sampling / Analysis Unit

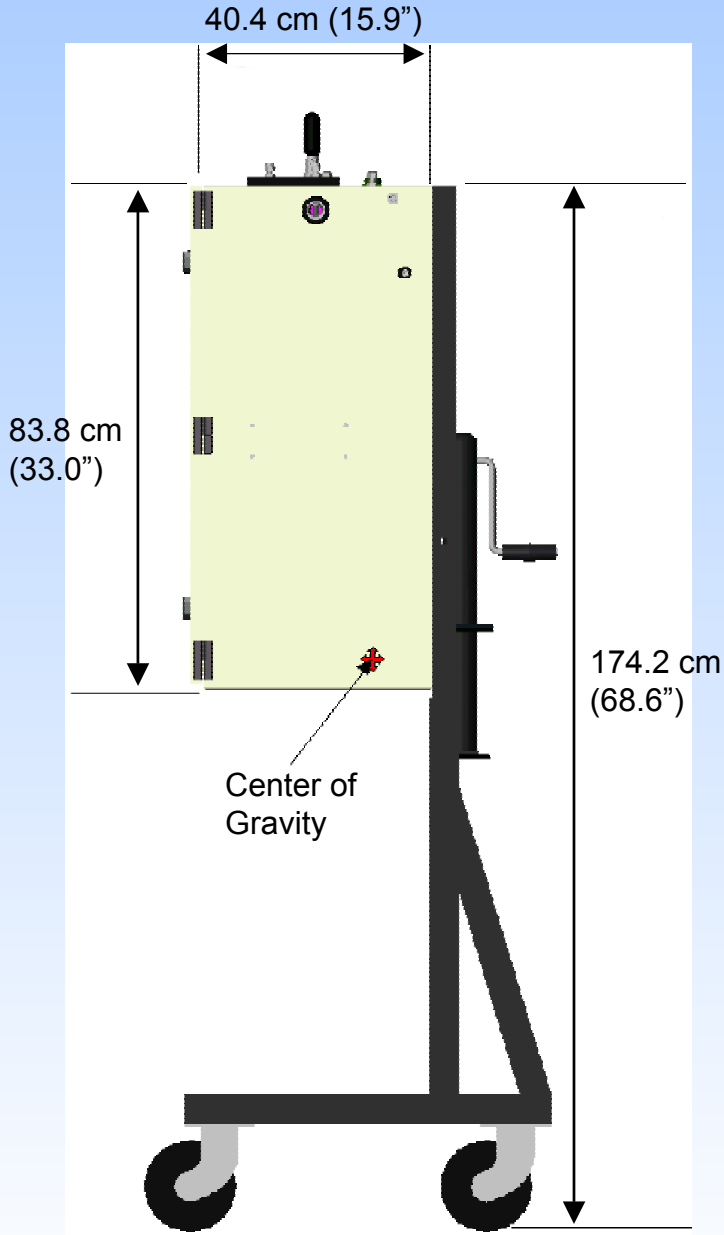


Furnace Assembly



Instrument Stand





Series 4200 Combustion Efficiency Monitor
Improving Accuracy

1. Start with a TEOM inertial mass balance.
2. Add sensitive thermal oxidation analysis technique.
3. Add microprocessor control for sample collection, handling and analysis.
4. Develop microprocessor-driven “smart” controls keep inertial mass measurement and thermal oxidation systems operating in their “sweet spots”.

Series 4200 Combustion Efficiency Monitor
Improving Accuracy (cont.)

5. Add new CO_2 detector with higher resolution and improved calibration stability.
6. Include open path, positive pressure CO_2 flow path design to eliminate measurement errors due to leaks.
7. Use dry, CO_2 free air as carrier gas for CO_2 analysis to improve baseline stability and signal resolution.
8. Use orifice-based Streamline™ flow sensor rather than drift prone mass flow controller.

Series 4200 Combustion Efficiency Monitor
Improving Reliability (and Maintainability)

- Sample Analysis System Improvements
  1. New furnace design uses reliable, long-life quartz cartridge heating elements and upgraded temperature control.
  2. Positive Pressure CO_2 Pneumatic Path eliminates troubleshooting effort and calibration errors due to leaks.
  3. Orifice-based flow sensor replaces less reliable, higher maintenance mass flow sensor/controller.
  4. Silicone tubing used internal sample line replaced with Teflon tubing.

Series 4200 Combustion Efficiency Monitor
Improving Reliability (and Maintainability)

- Sample Analysis System Improvements (cont.)

5. Employ sample transport tubing that is impervious to combustion gases and byproducts.
6. Upgrade sample line heaters to eliminate unexpected heater failures.
7. Mass Transducer Cooled to 180°C Rather than Ambient Temp. to Reduce Thermal Stress on Filter Cartridge.

Series 4200 Combustion Efficiency Monitor
Improving Reliability (and Maintainability)

- Sample Analysis System Improvements (cont.)
  8. Sample Processing Bench Assembly Uses Proven Pneumatic, Linear Slide Mechanism Concept From Partisol-Plus Ambient Particulate Monitor (>1000 currently operating).
  9. Use Linear Slide Mechanism to transport sample between analysis stations - motions accomplished using pneumatics; *no* belt- or motor-driven components.
  10. Design goal to eliminate moving parts where at all possible.

Series 4200 Combustion Efficiency Monitor
Improving Reliability (and Maintainability)

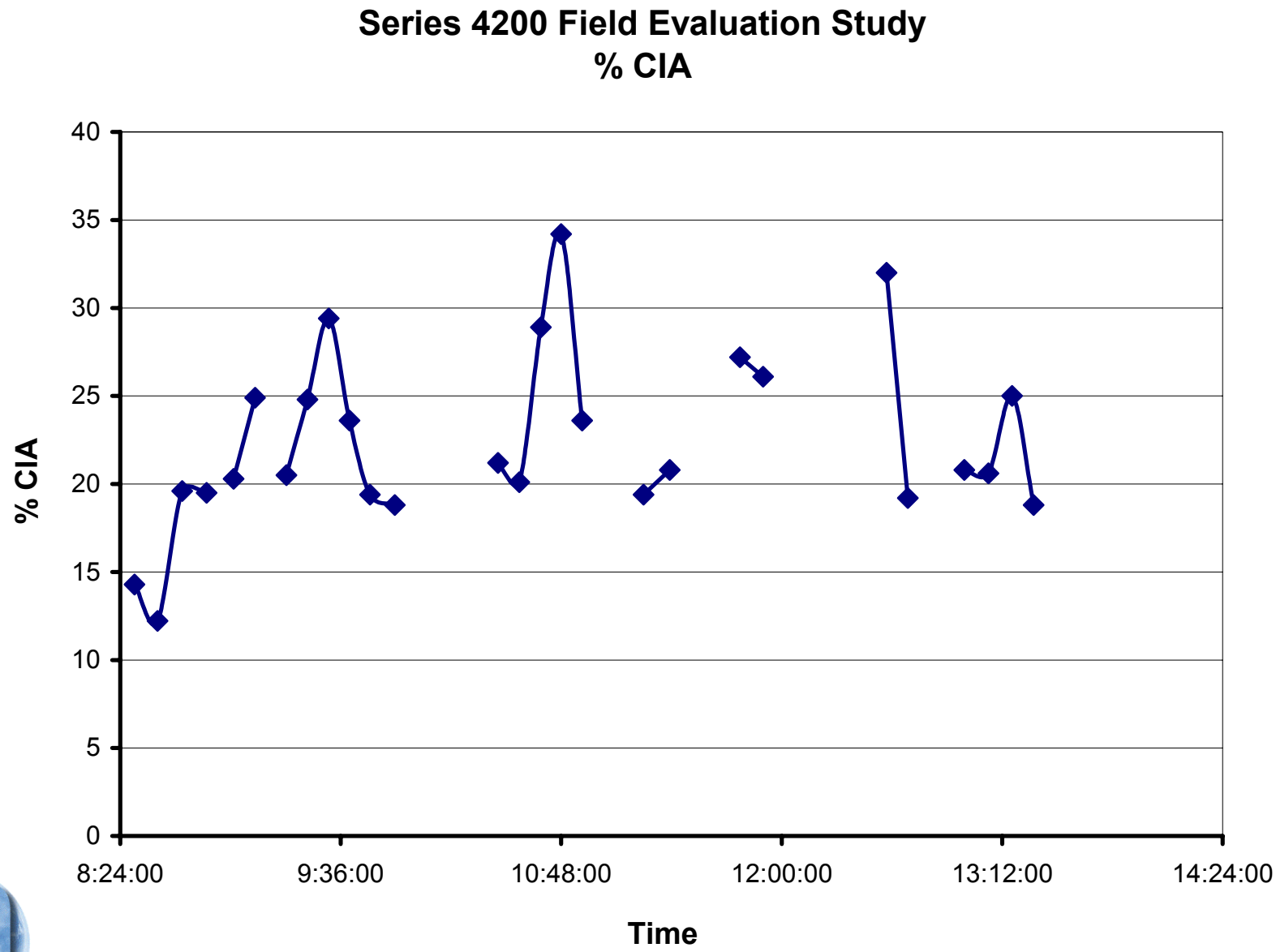
- Electronic System Upgrades

  1. Use microprocessor-based, electronic control, data acquisition and reporting systems based on proven design used in R&P 8400N Ambient Particulate Nitrate monitor.

  2. Incorporate LCD operator interface into electronics module to allow instrument operation, control and data output at monitor location.

  3. Windows™ - based, remote communications / data reporting software eases data reporting and analysis tasks for system operators and managers.

Series 4200
Field Trial Results and Data Examples


Series 4200 Field Evaluation Study
% CIA
40
35
30
25
20
15
10
5
0
% CIA
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10:48:00
12:00:00
13:12:00
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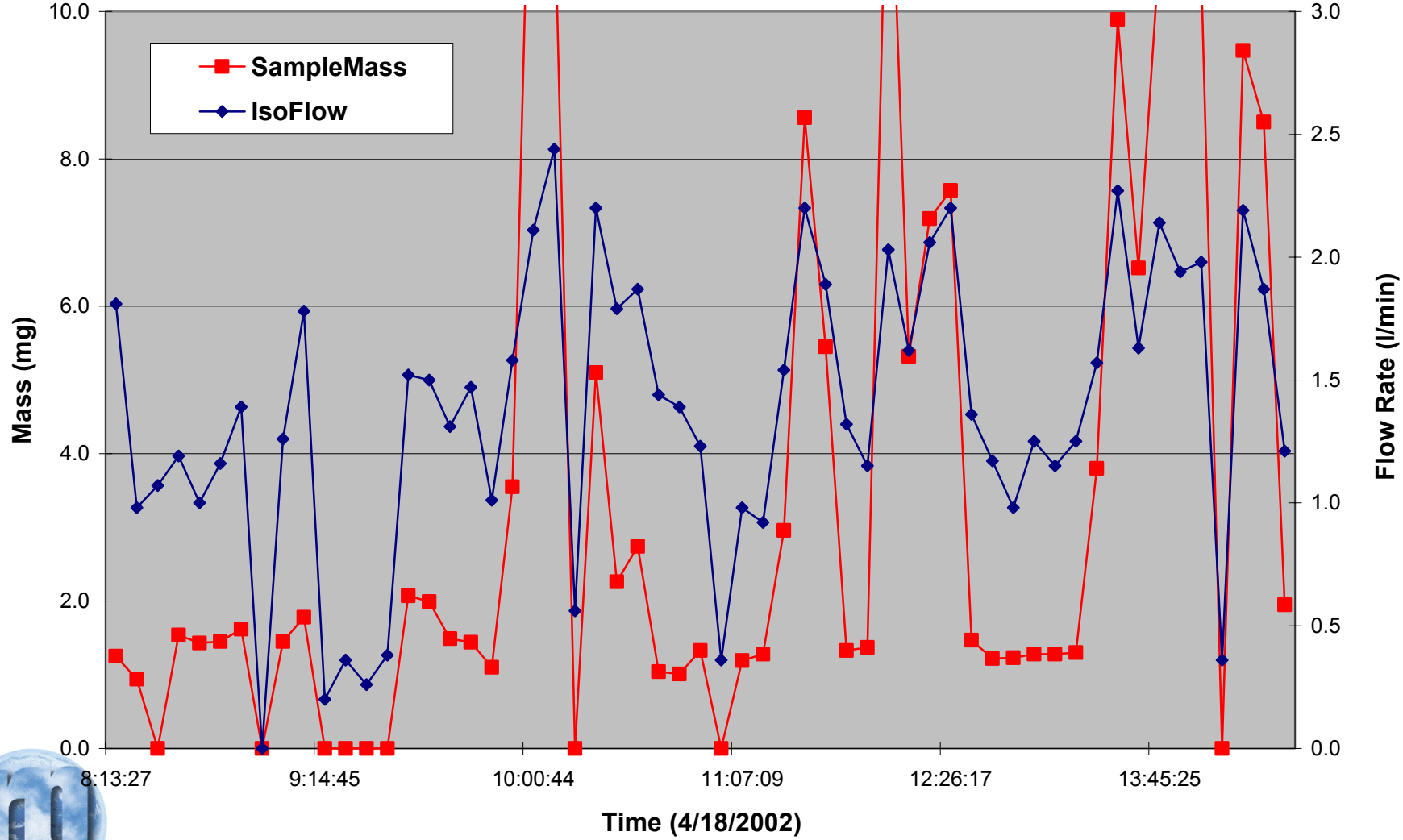
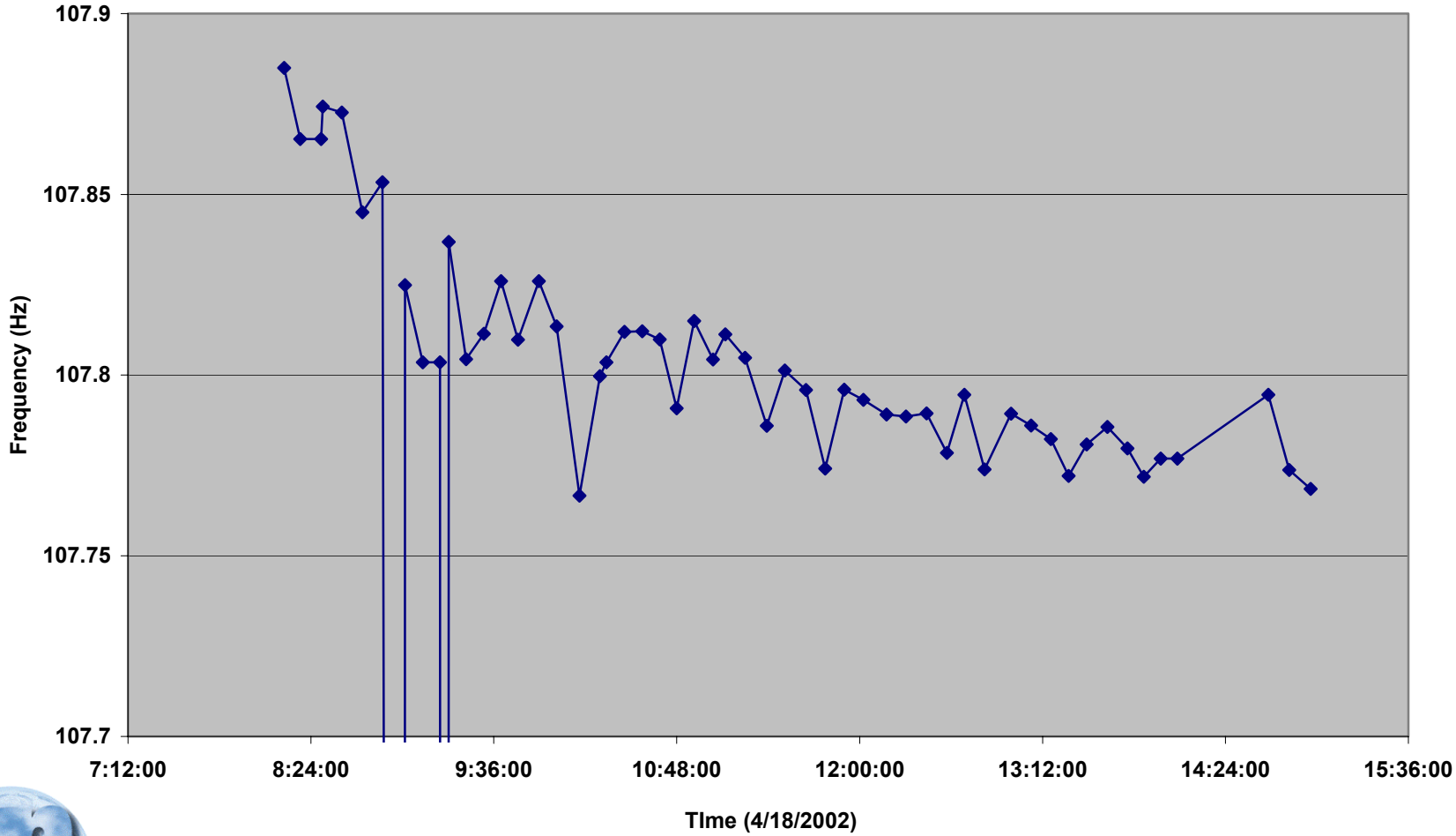
Time

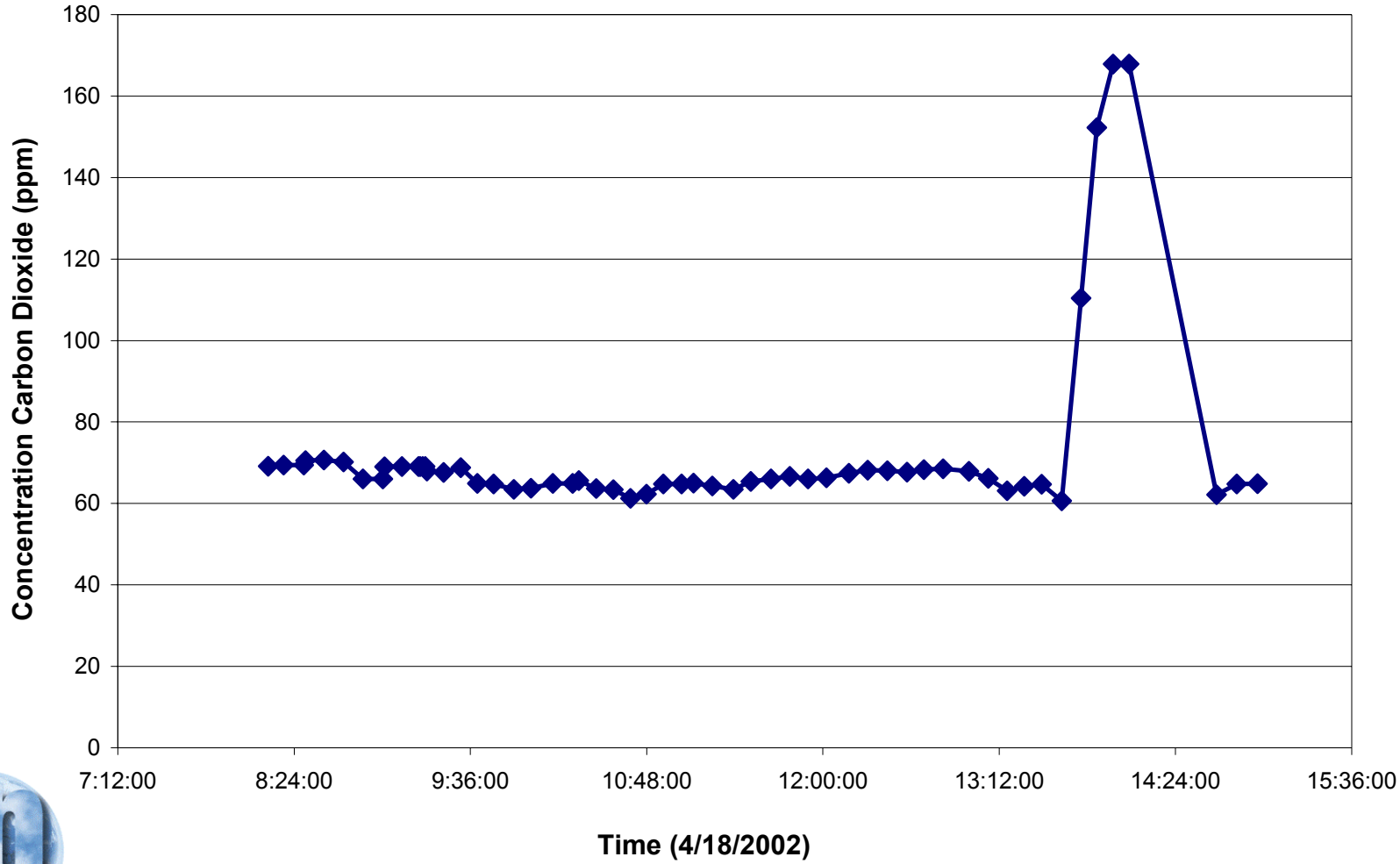
Series 4200 Field Evaluation Study
Mass Capture and Isokinetic Flow Rate



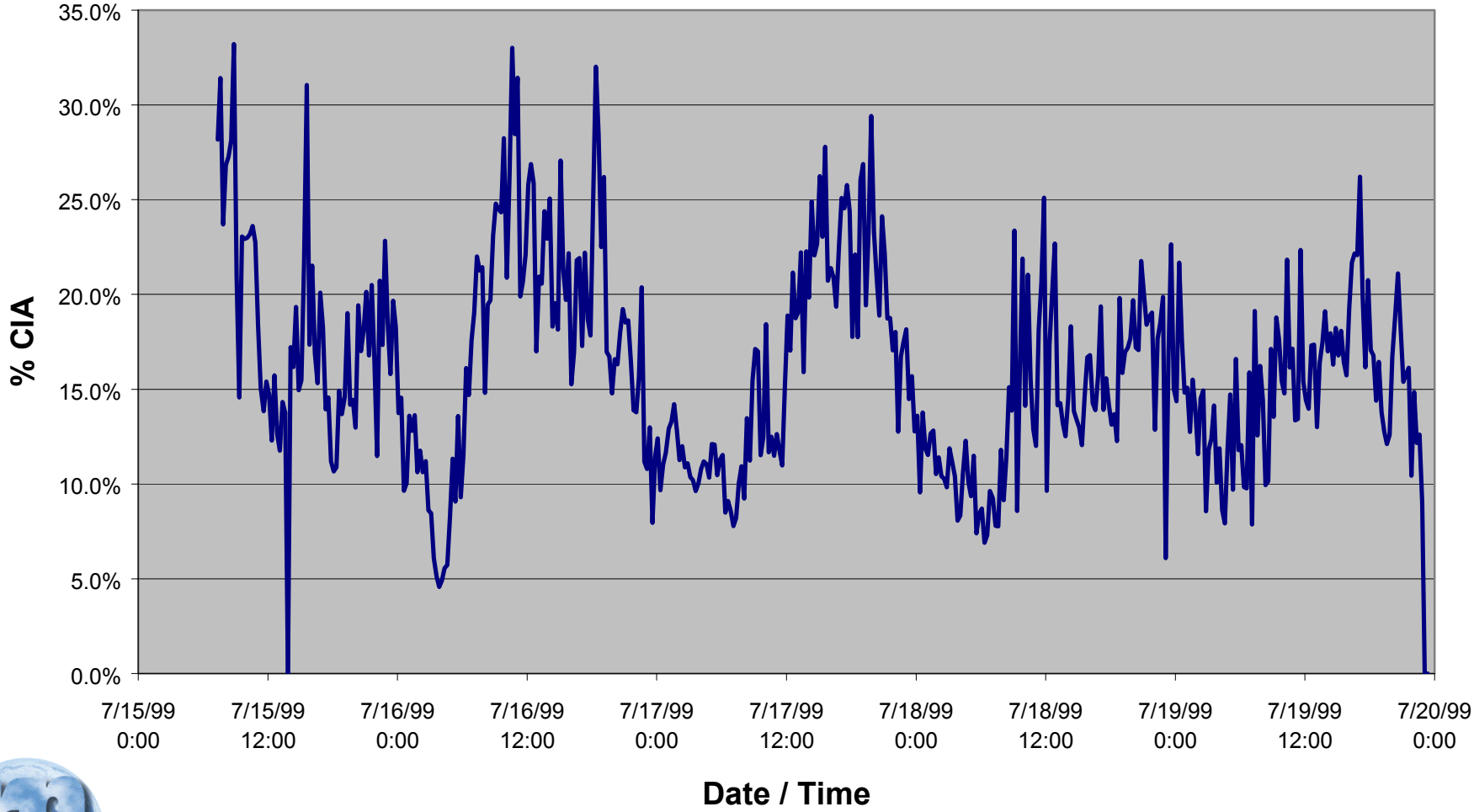
Series 4200 Field Evaluation Study
Analysis of Mass Transducer Baseline (f_0) Drift



Series 4200 Field Evaluation Study
Analysis of Baseline CO_2

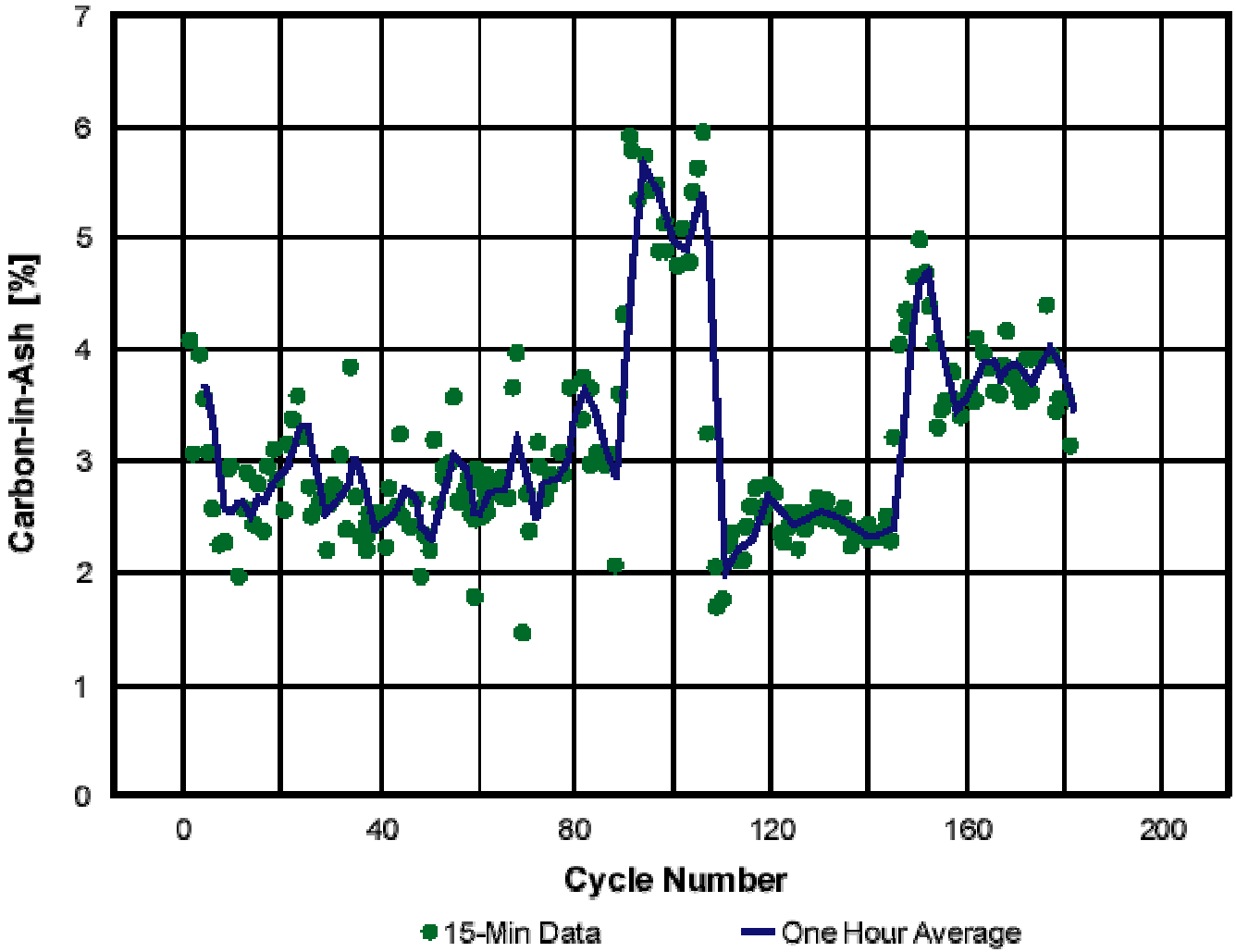


Model 4100 Carbon-in-Ash
E.C. Gaston Station
07/15 - 07/19/99



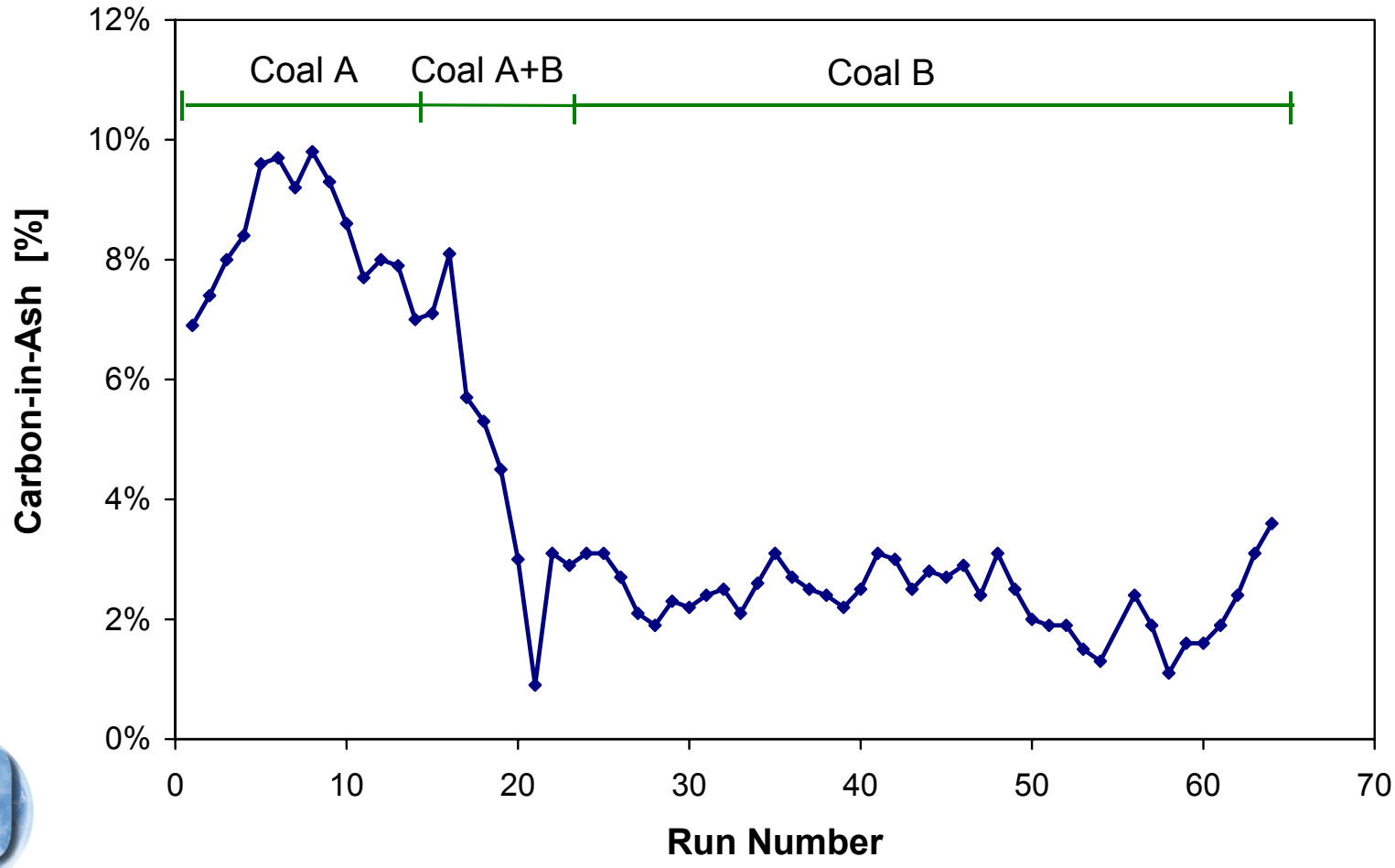
Carbon-in-Ash Results

Central Hudson, Danskammer Station



Results During Change of Coal Type

Korea Electric Power Corporation



Summary

I Series 4200 Combustion Efficiency Monitor

- Direct measurement technique generates carbon results independent of coal type.
- High resolution and accuracy ($\leq \pm$ 0.5% CIA).
- Isokinetic particulate matter sampling system.
- System is pneumatically driven—no pumps.
- Allows remote operation from plant control systems.
- Built in self tests and diagnostics that can be viewed remotely or at monitor location.
- Designed for minimal, routine maintenance.